

knowledge and of the meaning of personal identity, which must always most strenuously exercise our highest faculties. If there has been any marked shifting of ground, it has been towards the region of personal experience, a return to the principle of *cogito, ergo sum*, a principle of more metaphysical treasure than Descartes himself discovered. The living and dynamic nature of the self has come to stand out in more striking relief. The self-realisation of Hegel and the will of Schopenhauer, ideas so typical of the resolute individual character of western ethics, will illustrate one of the many lines along which Kant's impulse has acted. In nothing is he more emphatic than in urging the necessity of a critical inquiry into the foundations of knowledge before attempting to deal with the opposing dogmatisms of physics and metaphysics, and it is just the validity of his own *Kritik* which has made the later times so productive of reconstructions. The parts in our vast system of knowledge have at the same time become more and more related to an organic whole. More and more has the analogy of the living organism, with its parts in the whole and its whole in the parts, become descriptive of the body corporate of thought, and it may perhaps be said that it enters into our conceptions of the whole of being. Perhaps the full result of this idea in its religious aspect has not yet been realised. Certainly the living purpose of the abstract physical law has not yet been successfully formulated either by transcendentalist or materialist.

ALFRED EARL.

THE FORMATION OF CORAL REEFS.

CORAL reefs are divided into three classes, fringing, barrier and atoll. A fringing reef forms a terrace at the low tide level, extending out from the coast of any land, while a barrier reef is a rampart at the same level, lying parallel to the coast, from which it is separated by a deep channel. An atoll is a ring-shaped reef surrounding the lagoon, a basin varying up to 50 fathoms in depth; it is thus in no way connected with any land other than may form upon it.

A typical atoll has a flat encircling reef, generally with a series of islands upon it and a number of channels leading into its lagoon. Where land exists, the reef may be a mile or more broad, but commonly averages about 500 yards. Its surface is a flat of coral limestone almost completely bare of sedentary life. Towards the ocean its edge appears as if the waves were cutting a series of canals into it, but this appearance is really due to buttresses being built out from the rock behind by the reef organisms. Beyond this edge the bottom is extremely rough, but passes gradually into a more even slope. This area, the *reef platform*, may have hollows and pockets filled with debris, but its prevailing characteristic is its almost complete covering of corals, nullipores, Foraminifera, Polyzoa, and other sedentary organisms. At about 250 yards from the edge of the reef, where its depth is about 40 fathoms, it passes somewhat abruptly into a *steep* at a slope often exceeding 50°. This continues to about 140 fathoms, after which the slope, becoming quite moderate, passes gradually into the contour of the surrounding sea. The steep has never been properly investigated, but swabs bring up loose dead masses of such organisms as cover the reef platform above. Their presence is due to the undercurrents resulting from the sea striking on the atoll, which sweep down the reef platform, giving a talus slope (Fig. 3). Again, we have little knowledge of the lower slope down to 500 fathoms, where deep-sea life probably dominates. Shoals at such depths are densely covered with corals, but off atolls the lead only occasionally

brings up a cup. Probably sedentary life is far from scarce, as the fine coral mud, so deleterious to coral life, appears to be swept further out.

Lagoons vary greatly in accordance with their size and depth. A fairly open one has its bottom above the 25 fathom line either bare or covered with coarse sand, but deeper a fine mud may be found. Commonly the depth of any deep lagoon bears some proportion to the depths of the passages into it. Shoals occur anywhere in it, reaching the surface and forming broad flats. From the lagoon floor they arise abruptly, as does also the encircling reef (Fig. 3), a gradual slope to 20 fathoms or less covered with decaying coral masses, and then a perpendicular cliff to the surface.

The examination of the surface of the encircling reef shows it to have been formed by corals, bound together by other organisms. These corals form a definite class not extending below 25 fathoms in any luxuriance. They feed mainly—and many entirely—by their commensal algæ, so that they, as also the nullipores, are dependent for their growth on light and constant change of the water. They are profoundly affected by any deposition of mud, and for this reason upgrowing shoals are rare in lagoons except near passages. The enormous amount of mud formed is shown by its sinking as a deposit around atolls. The muddy water that streams out of the lagoons in stormy weather shows where it originates; but little can come from the surface of the reef, which is stationary in height, and still less from the reef platform, covered as it is by the bodies of living organisms. It is the result of the action of the boring and sand-feeding animals of the lagoons breaking up the coral skeletons and grinding them into the finest mud, much of which passes into suspension in the water. The corals on any low part of the encircling reef over which the lagoon water may pour are killed by this mud, leaving bare areas for the entrance of boring organisms, with the result that a new passage may be cut through the rim into the lagoon. That solution is also of great importance in the lagoons seems certain, for the mud at the bottom of such a lagoon as Suvadiva contains more than 2 per cent. of silica, whereas the sand of the reef has less than 0.04 per cent.

At 40 fathoms different genera of corals, not dependent on commensal algæ, dominate, and at the edge of the reef platform are the builders, their mortar consisting mainly of the encrusting *Polytrema*. They range from the surface, where they are almost choked out by others to 50 fathoms or more, and probably form an important connecting link between the surface builders and the true deep-sea corals, which in the tropics are seldom found above this latter depth. Their rate of growth, and also that of the surface forms, is enormous. Indeed, it would be moderate to estimate that a shoal at 25 fathoms would be built up to the surface in 1000 years, and that one at 50 fathoms would scarcely take more than twice as long.

Recent work has shown that all coral reefs can scarcely be explained on one method of formation. Four modes naturally suggest themselves.¹ (1) (Fig. 1) On any elevation on the bottom of the ocean sedentary animals naturally congregate. Their remains build up its summit to an extent out of all proportion to the upgrowth of the surrounding area, so that it ultimately approaches the surface. The deep-sea corals in warm latitudes give place to their intermediate depth allies, and these again to the reef builders, so that our peak is ultimately crowned with a surface reef. It will be readily understood from the

¹ A fuller consideration of some of the views here put forward will be found in "The Fauna and Geography of the Maldivé and Laccadive Archipelagoes," pp. 12-50, 146-183, 313-346 and 376-423.

description above of a typical atoll that such a reef extends outwards on its own talus to form a great broad plateau. Boring organisms enter on its central part and cause the rock to decay. Sand-feeders follow

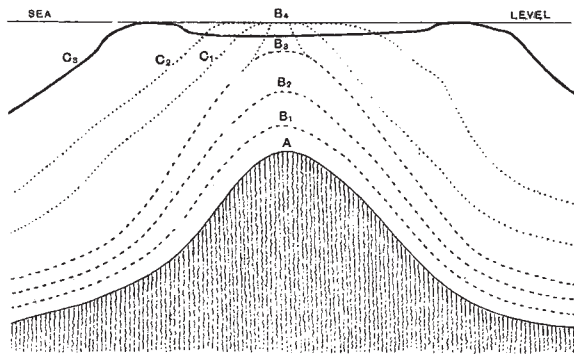


FIG. 1.—Diagram to illustrate the first method of formation of an atoll. A, Original mound on the sea floor. B 1-4, Growth of the same to form a surface reef. C 1-3, Extension outwards and formation of an atoll.

and triturate up the fragments, throwing a constant stream of fine mud into suspension in the water to be removed by the tidal and other currents. Assisted by the solubility of coral in sea-water, a lagoon is formed in the centre of the reef, and passages are cut later from it along the lines by which its muddy water escapes. The process may continue to form an atoll of the largest size, such even as Funafuti or any of the Ellice and Gilbert groups, which appear to have arisen on a single mountain range.

(2) (Figs. 2 and 3) The second method of formation depends on the power of the ocean currents to cut down land and form submarine banks. It is exemplified by the Maldives Group, the main chain of which is more than 300 miles long, and lies at right angles to the monsoon currents of the Indian Ocean. Here the action of the currents appears to have cut down a great tract of land, or at least a series of peaks, to form a plateau more than 100 fathoms in depth (Fig. 3). It is easy to see how the loose mass of cinders formed in a submarine eruption might be so cut down to 30 or even 50 fathoms, but this action, when first proposed for the Maldives, seemed extreme. It has, however, received strong support from the work of the Siboga Expedition in the East Indies. At depths below 50 fathoms it is obvious that from the first the organisms on the periphery of the bank so formed would grow up more rapidly, and so an atoll as such would directly arise (Fig. 2). The whole action might proceed extremely rapidly. Indeed, it is not unlikely that the shoal marking the site of what was once

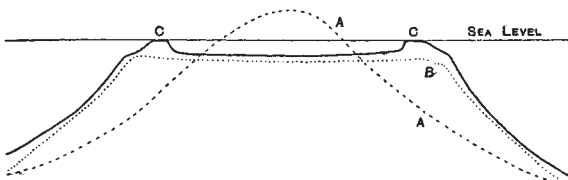


FIG. 2.—Diagram of the second method of formation of an atoll. A, Contour of the original island. B, The same cut down to form a plateau. C, The atoll reef.

Falcon Island, Tonga, will by 4000 A.D. be occupied by a considerable atoll. The action on a land like the Maldives, which is of considerable linear extent and of more solid construction, would proceed more slowly and show many modifications. A certain number of

channels would be retained and even deepened as the rim grew up. Each piece of rim as it formed would give a protected area behind itself around which the currents would sweep, and might thus become separated as a distinct bank or atoll. The same action might occur at two or three levels, and in this way the whole bank, instead of being crowned by one atoll ring, might be surrounded by a series of secondary atolls, their rims again formed by series of still smaller tertiary rings. This, in truth, appears to be the case in the Maldives, but the continued upgrowth of the rims of the secondary atolls is uniting the outer sides of the

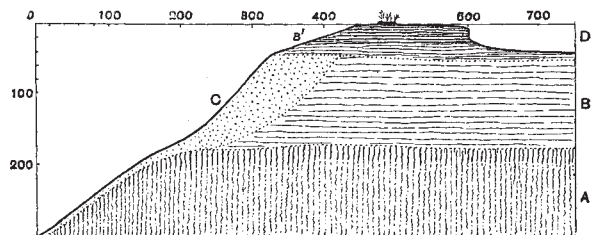


FIG. 3.—Section of the outer edge of one of the Maldives atolls. A, Foundation of primitive rock cut down by the currents. B B', Upgrowth of the rim by the deep-sea, intermediate depth and reef organisms. C, Extension outwards by means of the talus slope. D, Lagoon. (Scale in fathoms.)

tertiary rings, while their inner parts are being removed.

(3) (Fig. 4) A flat terrace is formed around the shore of an island by the action of the sea on the land, and is covered at its edge by reef organisms, or a fringing reef is formed. Subsequently, the edge of the terrace grows outwards and its inner part is removed as in (1), forming a barrier reef. Eventually, the original island, owing to similar causes, disappears, leaving an atoll. This method is of quite wide occurrence in

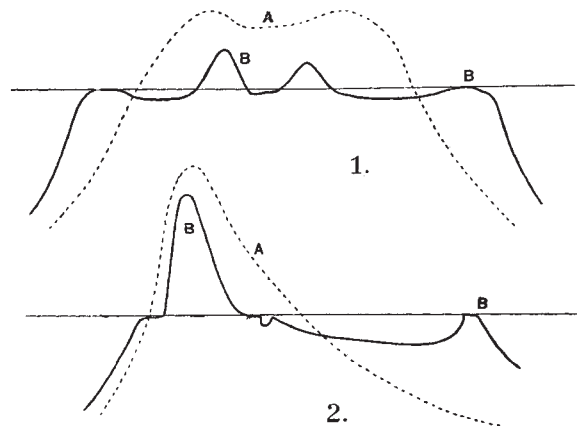


FIG. 4.—Sections across (1) Ongea Levu, Fiji, limestone, and (2) Wakaya, Fiji, volcanic, to illustrate the third method of formation. A, Supposed contour of the original land. B, Section across the existing land and reef. (Vertical scale many times the horizontal.)

areas where elevated coral reefs are found (Fig. 4, 1). Every stage can be followed in the limestone islands of the Fiji group. It also occurs, though much more slowly, around other islands. A good example is Wakaya, Fiji, which has to the west a broad fringing reef, half formed by a terrace cut out of the land and half by a true coral formation, and to the east a barrier reef separated by a channel $3\frac{1}{2}$ miles from the land, which still retains a definite terrace of the volcanic rock (Fig. 4, 2).

(4) Lastly, the subsidence of land might give a suitable foundation on which a reef could *build up to the surface* either as an atoll or subsequently to form one. It has no doubt constantly produced large areas where (1) and (2) could act, but, where it has directly brought about the formation of atolls, it has probably been a purely local phenomenon. In no case can the mere existence of any atoll or reef be considered as evidence of any subsidence. Certain elevated reefs appear possibly to have owed their origin to this mode of formation, but there is no definite evidence in support of it for any existing reef, though certain reefs in the East Indies and to the south-west of the Indian Ocean may have so originated.

The first three modes of formation resemble one another in that to produce the characteristic forms of reefs they depend on factors which can be clearly seen in progress at the present day. Indeed, on each atoll may be found the same influences at work as produced its structure and appearance. The topography of the numerous submerged tropical banks of the Indo-Pacific region, that reach within 50 fathoms of the surface, strongly supports (1) and (2), but the examination of others at greater depths, such as the Saya de Malha and Nazareth, is exceedingly desirable. More light, too, is imperatively demanded on the conditions and life of atoll slopes and shoals from 50 to 500 fathoms, where the characteristic deep-sea conditions would seem to prevail. The study of the fauna also down to these depths over any large region or ocean may confidently be expected to throw a flood of light on the distribution of marine forms, and thus enable us to predict with some additional degree of certainty the former distribution of land and sea.

J. STANLEY GARDINER.

PHOTO-TELEPHONY.

THE transmission of speech by light was first realised nearly a quarter of a century ago by the invention of Prof. Graham Bell's photophone, a full description of which will be found in *NATURE*, vol. xxiii. p. 15. The transmitting instrument contained a small silvered disc or diaphragm of thin microscope cover-glass, which was clamped around the circumference like the diaphragm of a telephone. The receiver was a large parabolic mirror, at the focus of which was fixed a selenium cell in circuit with a telephone and battery. A beam of light from the sun or an electric lamp was reflected by the silvered diaphragm to the parabolic mirror, which concentrated the rays upon the selenium cell. The speaker's voice was directed upon the back of the diaphragm, causing it to vibrate in correspondence with the sound waves; the rapid changes in the curvature of its surface which accompanied the to and fro movements of the central parts of the diaphragm varied the concentration of the light upon the selenium, and since the conductivity of the selenium varied with the illumination, sounds were produced in the telephone similar to those by which the transmitting diaphragm was agitated.

Though the performance of the photophone was for short distances surprisingly perfect, it failed for several reasons to give satisfactory results when the transmitter and the receiver were separated by more than two or three hundred yards, and for a long time all attempts to render the invention practically useful were abandoned. The resuscitation of the photophone in a modified form has resulted from the recent discovery of the "speaking arc."

A few years ago Dr. H. T. Simon, of Göttingen, having noticed the curious sounds given out by an arc lamp when one of its leads happened to be near a wire

supplying intermittent currents to an induction coil, was led to try the effect of superposing a microphone current upon the current feeding the lamp. With this object he interposed the secondary coil of a suitable transformer into one of the lamp leads, while the primary coil was connected in circuit with a battery of two or three cells and an ordinary microphone, the latter being placed in a distant room. Words spoken into the microphone were distinctly repeated by the arc, which was found to constitute an excellent telephone receiver. The simple arrangement originally employed by Dr. Simon has since been modified in some details, notably by Mr. W. Duddell, who in 1900 caused an arc lamp to address a large audience in the hall of the Institution of Civil Engineers.¹ That such an effect should be produced by so small a cause as the feeble induced microphonic currents is surprising; Mr. Duddell has, however, shown experimentally that a periodic variation of the order of 1 part in 10,000 of the mean current supplying the arc will alter the vapour column sufficiently to produce sound-waves.

No change of luminosity while the arc is talking can be recognised by the eye, but if the light is caused to pass through a transverse slit upon a moving kinematograph film the developed negative shows a succession of narrow bands of varying brightness, indicating that considerable changes actually do occur in the intensity of the light.

Prof. Graham Bell suggested in 1899 that the speaking arc might be used as transmitter in phonographic work. His suggestion has been followed up with conspicuous success by Dr. Simon himself and by Mr. Ernst Ruhmer, of Berlin, the latter having been able to transmit intelligible speech across distances up to 15 kilometres. As a transmitter he uses a search-light projector having a parabolic mirror of silvered glass at the focus of which is the speaking arc; the carbons are placed horizontally along the axis of the mirror with the positive carbon outwards. A small telescope serving as a finder may conveniently be attached to the projector. The light is received, as in the older apparatus, by another parabolic reflector having a cylindrical selenium cell fixed axially at its focus. It is chiefly to the peculiar quality of his selenium cells that Mr. Ruhmer attributes the excellence of his results. The cells are of a pattern proposed by the present writer in 1880 (*NATURE*, vol. xxiii. p. 59). Two thin wires serving as electrodes are wound spirally, very close together but not touching, around a cylinder of unglazed porcelain, upon which a fine double screw-thread (to receive the wires) has been formed before baking. The surface of the cylinder is covered with a thin coating of selenium, which is afterwards crystallised; thus the two wire electrodes are joined throughout their length by the sensitive substance. Great importance is attached to the mode in which the crystallisation is effected. Vitreous selenium may be crystallised either, as is usually done, by gradually heating it up to a temperature somewhat above 100° C. or by melting it at a high temperature—about 250°—and letting it gradually cool down. In the latter case the crystalline surface appears to be of a coarsely granular structure, and it has long been known to the writer that selenium thus prepared is much less affected, as regards conductivity, by changes from darkness to light than the fine-grained variety obtained by the other process. This is confirmed by Mr. Ruhmer, but he has added the further interesting observation that the coarse-grained kind—"soft" selenium he calls it—is immensely more sensitive than the other, or "hard" selenium, to small changes of illumination, and, moreover, that it re-

¹ A detailed description of his apparatus is given in *Journ. Inst. Electrical Engineers*, vol. xxx. p. 240.